

Nutritional Composition of Four Underexploited Wild Fruits in Mali

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Abstract

Malnutrition and food insecurity are major concerns for the Malian authorities. The objective of this study was to strengthen the knowledge about the nutritional and physicochemical values of four underutilized edible wild fruits picked at two cities belonging to different bioclimatic zones of Mali. The physicochemical and nutritional parameters were performed using standard methods. The findings revealed that all these parameters varied from one fruit to another, this outcome could be associated with the provenances of the wild fruits (p-value < 0.05). The protein contents varied from 4.53 g/100g by dry matter (DM) for *R. sudanica* fruits to 5.34 g/100g DM for those of *B. aegyptiaca*, all these samples were being harvested from Sikasso. The highest concentrations of vitamins are C (150,800 to 151,000 µg/100g DM), E (1,310 to 1,350 µg/100g DM) and A (38 to 40 µg/100g DM) respectively for the fruits of *Z. mauritiana*, *B. aegyptiaca* and *S. senegalensis*. In addition, these fruits would constitute a potential source of minerals such as iron, phosphorus and calcium. Thereby, these fruits are promising raw materials to be used against the malnutrition linked to the micronutrients deficiencies and the management of certain pathologies related to oxidative stress.

Keywords

Wild Fruits, Nutritional Values, Provenances, Malnutrition, Food Insecurity

1. Introduction

“Hungry people cannot be educated, cannot be cared for themselves and cannot ensure sustainable economic growth”, said Brouwer *et al.* [1]. This introductory note to the proceedings of the 2nd International Workshop on the Food Pathways to Improve Nutritional Situations in West Africa shows that malnutrition and food insecurity are recurrent problems. This is why nutrition is increasingly recognized as a basic pillar for social and economic development. The efforts to reduce malnutrition and mortality, especially among children, are essential to contribute to achieving the Sustainable Development Goals [2].

Sub-Saharan Africa and Mali, in particular, remain vulnerable to these troubles. The nutrition indicators show that the situation is alarming. According to the estimates of FAO (2019) [3], the number of undernourished people has started to increase back since 2015, and more than 30% would be in Africa. An in-depth analysis of the FAO statistics on this field revealed that the number of people affected by chronic food insecurity in 2017 was 821 million, *i.e.*, the ninth of the world population. Among them, more than 38 million children under five years old were overweight, 25% of them in Africa [3]. In addition, it is estimated that more than one-third of deaths in children under five years old in Africa are directly or indirectly caused by malnutrition [2]. In Mali, recent studies have shown that 27% of children under 5 years old are chronically malnourished and 10% of them are severely stunted. Nearly ten percent of children under 5 years old (9%) are suffering from severe malnutrition, the same studies also revealed that 19% are underweight [4].

To face these troubles, human has always resorted for many centuries, to wild food products. In recent years, there has been an increasing interest in the scientific world around these wild food products. Many studies carried out in Mali have shown that the Malian flora is very rich in wild food plants [5] [6] [7]. Other studies conducted on some of these edible wild plants have shown that they are rich in micronutrients [8] [9] and also in macronutrients [10] [11]. However, many other food wild species are not explored yet. Among them, there are *Balanites aegyptiaca*, *Saba senegalensis*, *Ziziphus mauritiana* and *Raphia sudanica*. However, despite the increasing interest in these food wild fruits and according to our knowledge, their nutritional potential is still not well known in Mali and consequently, they are underexploited and under valorized. That is why this study aims to contribute to the fight against malnutrition in Mali through an evaluation of the nutritional composition of these four food wild fruits, namely *Balanites aegyptiaca*, *Saba senegalensis*, *Ziziphus mauritiana* and *Raphia sudanica* harvested in two different bioclimatic zones of Mali.

2. Material and Methods

2.1. Material

The vegetal material was consisted of the wild fruits of *Balanites aegyptiaca*, *Saba*

senegalensis, *Ziziphus mauritiana* and *Raphia sudanica*. The first three ones were collected in the markets of Banamba (from the Sahelian zone) and Sikasso (from the Sudanese zone). The latter (*Raphia sudanica*) was collected from Sikasso because of its geographical specificity. These sites were chosen taking into account the food security, accessibility and especially the availability of these fruits.

2.2. Methods

2.2.1. Physicochemical Parameters

❖ pH and total free acidity

The AFNOR methods [12] were used to evaluate the pH and the total free acidity.

Ten grams (10 g) of powdered samples were homogenized with 50 mL of distilled water using a magnetic stirrer (Velp Scientifica, Cheshire, Great Britain). The pH of the homogenate was determined using a digital pH meter (Knick type 647, Interface Technology, Germany) calibrated with the standard buffer solutions (pH 4.0 and pH 7.0) at 25°C.

After centrifugation of the homogenized solution above, the supernatant was collected and used for the assessment of the total free acidity by titrimetric assay. The suspension was titrated with an alkaline NaOH solution (0.1 N) using the phenolphthalein solution as colored indicator [12]. The total acidity was expressed as a percentage of lactic acid [13] according to the following Formula (1):

$$\text{Total free acidity (\%)} = \frac{V * N * M}{W_i} \times 100 \quad (1)$$

V : Volume of NaOH used (L);

N : Normality of NaOH solution (0.1 N);

M : Molecular weight of lactic acid (90 g/mol);

W_i : Initial sample weight (g).

❖ Humidity

The humidity content was determined by differential weighing according to the French standard NF V 03-707 [14]. Ten grams (10 g) grams of sample powder were weighed in crucible before (W_1) and after (W_2) passing in an oven at 105°C for 16 h to 18 h. The humidity content for 100 g of sample was deduced using the formula below (2).

$$\text{Humidity content (\%)} = \frac{W_2 - W_1 (\text{g})}{\text{Initial sample weight (g)}} \times 100 \quad (2)$$

❖ Total ashes

The total ash content was evaluated by incineration using an oven (Volca V50 Prolabo) according to the standard ISO 2171 [15]. Ten grams (10 g) grams of sample powder were weighed in crucible before and after passing in an oven at 550°C ± 5°C. The total dry matter content was calculated according to the following Formula (3):

$$\text{Total ash content (\%)} = \frac{\text{Weight of ashes (g)}}{\text{Initial sample weight (g)}} \times 100 \quad (3)$$

2.2.2. Nutritional Composition

❖ Total protein contents

The protein's levels were assessed by the determination of the total nitrogen according to the Kjeldhal method (NF V03-050, 1970) [16]. Thus, 1 g of sample powder dissolved in 5 mL of concentrated sulfuric acid was mineralized using a mineralizer (Velp Scientifica, Cheshire, Great Britain) in the presence of Kjeltabs catalyst. The obtained mineralized sample was purified by distillation (Velp Scientifica UDK 159, Cheshire, Great Britain). The nitrogen was then quantified by titration with HCl, 1 N. The total protein content was deduced from the nitrogen content using a conversion coefficient of 6.25 [16].

❖ Fat contents

The fat content was assessed by the gravimetric method after Soxhlet extraction using petroleum ether according to the standard ISO 659, (1998) [17]. The extraction was carried out hot (70°C - 75°C) by soaking 5 g of powder followed by rinsing with petroleum ether. After 6 - 8 hours of extraction, the petroleum ether was evaporated using an evaporator (Buchi CCT C21-901, Merck, Schnelldorf, Germany). After drying in an oven, the fat content was expressed as percentage of dry matter (% DM) using the following Formula (4) [17]:

$$\text{Fat content (\% DM)} = \frac{W_1 - W_0}{W_s} \times 100 \quad (4)$$

W_0 : Weight of the empty balloon (g);

W_1 : Weight of the balloon after extraction and drying (g);

W_s : Initial sample weight (g).

❖ Total and reducing sugar contents

The total and the reducing sugar were estimated by spectrophotometric method.

Preparation of extracts

In a test tube, 1 g of the sample was dispersed in 10 mL of 25% dimethyl sulfoxide (DMSO) in water (v/v). The mixture was incubated in a boiling water bath for 15 min. A volume of 0.1 mL was then taken and made up to 100 mL with distilled water.

Quantification

The total sugars were assayed using the colorimetric method described by Fox & Robyt [18]. A volume of 0.5 mL of the previously prepared extract was added to 0.5 mL of 5% phenol solution. After homogenization, 2 mL of 75% H₂SO₄ was added. After homogenization, the tubes were placed in a boiling water bath (100°C) for 20 min, then cooled on ice and in the dark for 20 min. After returning to the ambient temperature (25°C - 30°C), the absorbances were read at 490 nm with a spectrophotometer (Thermo Scientific Helios Epsilon). The concentrations of total sugars of the extracts were deduced from a standard curve of

D-glucose established in the same conditions as the extracts.

To quantify the reducing sugars, the colorimetric method with a DNS solution as reagent was used [19]. A volume of 0.1 mL of the prepared extract was diluted with 0.5 mL of distilled water. To this solution, 1 mL of DNS reagent was added. After homogenization, the tubes were placed in a boiling water bath (100°C) for 5 min, then cooled on ice and in the dark for 15 min. After returning to the ambient temperature (25°C - 30°C), the absorbance was read at 540 nm. The concentrations of reducing sugars of our extracts were deduced from a standard curve of D-glucose established in the same conditions as the extracts.

The values of total and reducing sugars were expressed as percentage of dry matter (% DM).

❖ Energy value

The energy value was calculated according to the Atwater coefficients [20].

Energy value (Kcal/100g DM) = % proteins × 4 Kcal + % carbohydrates × 4 Kcal + % lipids × 9 Kcal

❖ Mineral contents

The determination of mineral elements (Na, K, Ca, P, Fe, Mg, Mn, Zn, Cu, Ni, Pb, Co) was carried out by flame atomic absorption spectrometry according to AOAC (2012) [21].

A quantity of 0.5 g of sample was mineralized by progressive heating from 100 to 300°C in the presence of nitric acid solution (5%) for 90 min. After an ultrasonication treatment for 30 min at 80°C, the mineralized material was centrifuged (Ohaus® centrifuge) at 1000 rpm for 5 min. The absorbance was read using an atomic emission spectrometer (Perkin Elmer Optima 8000, Waltham, USA). The mineral concentrations were deduced from the standard ranges established under the same conditions as the extracts.

❖ Vitamins contents

Preparation of the sample

The extraction was carried out according to the method described by Kini *et al.* [8] with the wild fruit species. To 0.5 g of sample were added 10 mL of a solution of 10% KOH in methanol-water mixture (1: 1; v/v). To avoid oxidation processes (with fat-soluble vitamins: A and E) during saponification, 0.025 g of ascorbic acid was added. The mixture is then brought to reflux in a water bath at 70°C for 30 min. After cooling, the mixture was extracted with 3 × 5 mL of hexane. The hexane based phases were combined and dried over anhydrous sodium sulfate and then evaporated. The dry residue obtained was dissolved in HPLC grade methanol for analysis.

Quantification

A High Performance Liquid Chromatography (HPLC) method was used to quantify the content of vitamin A (β -carotene or provitamin A), vitamin E (α -tocopherol) and vitamin C. The HPLC (Agilent) was equipped with a 20 μ L injection valve, an Alumina-C18 column and a visible UV detector. The mobile phase consisted of an acetonitrile/methanol (80:20 v/v) mixture with a flow rate of 1 mL/min. The standards used were trans-retinol for vitamin A, α -tocopherol for

vitamin E and ascorbic acid for vitamin C.

2.3. Statistical analysis

The data obtained were processed using an Excel® spreadsheet version 2013. The statistical analysis was performed using Minitab 18.1 software (Minitab Inc., PA, USA). All measurements were performed in triplicates, and the values were expressed as mean values \pm standard deviation. The differences between samples were assessed using the one-way ANOVA via Fischer test. The differences between the samples were considered significant at $p < 0.05$.

3. Results and Discussion

3.1. Physicochemical Parameters

The results related to the physicochemical characteristics are presented in **Table 1**.

Table 1 reveals that all these physicochemical parameters varied from one fruit to another (p -value < 0.05). This same trend is observed in the areas of origin (Banamba and Sikasso). The pH and the total free acidity varied from one fruit to another (p -value < 0.05). On the other hand, no significant difference was observed between these two parameters in the ecological zones (p -value > 0.05). The pH varied respectively from 2.80 ± 0.19 for Saba of Banamba to 3.92 ± 0.21 for Balanites of Sikasso. The lowest total acidity was recorded in Balanites of Sikasso with $0.85\% \pm 0.05\%$ lactic acid equivalents and the highest in Saba of Banamba with $2.38\% \pm 0.08\%$ lactic acid equivalents (**Table 1**). The fruits of *Saba senegalensis* are the richest one in water with contents ranging from $19.03\% \pm 0.67\%$ to $21.66\% \pm 0.18\%$ (**Table 1**).

Table 1. Physicochemical characteristics of the fruits (for 100 g DM).

Fruits and provenances	Physicochemical parameters			
	pH	Free acidity* (%)	Humidity (%)	Total ashes (%)
<i>Balanites</i> of Sikasso	3.92 ± 0.21^a	0.85 ± 0.05^c	14.33 ± 0.94^e	6.38 ± 0.33^a
<i>Balanites</i> of Banamba	3.87 ± 0.28^a	0.88 ± 0.07^c	17.97 ± 0.25^c	5.84 ± 0.08^b
<i>Saba</i> of Sikasso	2.82 ± 0.17^c	2.28 ± 0.11^a	21.66 ± 0.18^a	2.37 ± 0.12^e
<i>Saba</i> of Banamba	2.80 ± 0.19^c	2.38 ± 0.08^a	19.03 ± 0.67^b	2.33 ± 0.14^e
<i>Ziziphus</i> of Sikasso	3.05 ± 0.18^{bc}	1.10 ± 0.06^b	10.62 ± 0.07^f	4.53 ± 0.31^{cd}
<i>Ziziphus</i> of Banamba	3.25 ± 0.22^b	1.07 ± 0.06^b	10.56 ± 0.86^f	5.03 ± 0.59^c
<i>Raphia</i> of Sikasso	3.73 ± 0.29^a	0.89 ± 0.07^c	16.27 ± 0.12^d	4.13 ± 0.08^d
p-value	0.33E-4	0.19E-12	0.03E-10	0.03E-8

*For each parameter, the means by column which do not share any letters (a-g) are significantly different at the probability threshold of 0.05. The total acidity is expressed in % equivalents of lactic acid for 100g of dry matter (DM).

3.2. Nutritional Composition

3.2.1. Macronutrients

The nutritional composition of our fruits is written down in **Table 2**.

The data from **Table 2** show that all the performed nutritional parameters varied from one fruit to another (p -value < 0.05). Excepted the fruits of *Balanites*, there is also a zonal variation for all these nutritional parameters. The protein contents of our samples have varied from 4.53 ± 0.25 g/100g DM for *Raphia* fruits to 5.34 ± 0.52 g/100g DM for those of *Balanites* all harvested in Sikasso (**Table 2**). Regarding the total carbohydrate contents, they have varied from 53.937 ± 0.61 g/100g DM for the fruits of *B. aegyptiaca* to 71.02 ± 1.95 g/100g DM for those of *Z. mauritiana*. For the reducing sugars, the highest levels were observed in the fruits of *S. senegalensis* (**Table 2**). The fruits of *R. sudanica* showed quite high fat contents with 16.49 ± 0.49 g/100g DM. The highest calorific power was observed in the fruits of *Z. mauritiana* from 350.90 ± 5.37 to 361.92 ± 8.63 Kcal/100g DM (**Table 2**).

3.2.2. Micronutrients

❖ Vitamins levels

Table 3 summarizes the levels of vitamins of our fruits.

The levels of vitamins have varied from 11 to 40 μ g/100g DM for vitamin A; from 90,000 to 151,000 μ g/100g DM for vitamin C and from 100 to 1350 μ g/100g DM for vitamin E. The fruits of *Z. mauritiana* are the richest one in vitamins C (from 150,800 to 151,000 μ g/100g DM), those of *B. aegyptiaca* have the highest levels of vitamins E (from 1310 to 1350 μ g/100g DM) (**Table 3**). Furthermore for all the performed vitamins, it appears an inter-fruit variation (p -value < 0.05) without significant variation between the geographical areas (p -value > 0.05), except the fruits of *S. senegalensis* about the vitamin C.

Table 2. Nutritional composition for 100 g DM.

Fruits and provenances	Nutritional parameters				
	Proteins (g/100 DM)	Fats (g/100 DM)	Carbohydrates (g/100 DM)	Reducing sugars (g/100 DM)	Energy values (Kcal/100g DM)
<i>Balanites</i> Sik	5.34 ± 0.52^{ab}	02.05 ± 0.11^d	61.45 ± 2.31^b	32.90 ± 0.55^c	285.65 ± 9.14^d
<i>Balanites</i> Bba	4.87 ± 0.05^{cd}	00.96 ± 0.03^e	53.93 ± 0.61^c	21.01 ± 1.71^d	243.84 ± 22.84^e
<i>Saba</i> Sik	4.83 ± 0.19^{cd}	04.60 ± 0.31^c	59.93 ± 1.77^b	41.66 ± 2.77^a	300.43 ± 5.92^c
<i>Saba</i> Bba	5.24 ± 0.19^{bc}	04.86 ± 0.10^c	62.63 ± 1.14^b	40.78 ± 1.32^{ab}	315.21 ± 4.20^b
<i>Ziziphus</i> Sik	5.70 ± 0.14^a	06.11 ± 0.09^b	71.02 ± 1.95^a	36.04 ± 0.91^{bc}	361.92 ± 8.63^a
<i>Ziziphus</i> Bba	5.49 ± 0.18^{ab}	05.80 ± 0.16^b	69.18 ± 1.25^a	32.10 ± 2.30^c	350.90 ± 5.37^a
<i>Raphia</i> Sik	4.53 ± 0.25^d	16.49 ± 0.49^a	34.47 ± 1.53^d	12.18 ± 1.58^e	304.39 ± 8.90^{bc}
p-value	0.001	0.10E-18	0.02E-10	0.45E-10	0.01E-8
AJR*	48 - 50 g	25 - 32 g	189 - 212 g	-	2120 - 2600 Kcal

*The means by column which do not share any letters (a-e) are significantly different at 0.05. AJR: Recommended daily intake for children 9 - 15 years old (Source: Elidrissi Slitine *et al.* (2010) [22]. Sik: Sikasso; Bba: Banamba.

Table 3. Levels of vitamins.

Fruits and provenances	Quantified vitamins ($\mu\text{g}/100\text{g DM}$)		
	Vitamin A (β -carotene)	Vitamin C (ascorbic acid)	Vitamin E (α -tocopherol)
<i>Balanites</i> of Sikasso	16.50 \pm 1.04 ^c	18,050 \pm 145.26 ^e	1310 \pm 55.68 ^a
<i>Balanites</i> of Banamba	18.00 \pm 1.00 ^c	17,880 \pm 138.09 ^e	1350 \pm 70.00 ^a
<i>Saba</i> of Sikasso	40.00 \pm 2.65 ^a	122,000 \pm 104.93 ^c	100 \pm 7.00 ^d
<i>Saba</i> of Banamba	38.00 \pm 2.00 ^a	131,000 \pm 804.34 ^b	110 \pm 4.36 ^d
<i>Ziziphus</i> of Sikasso	29.00 \pm 2.65 ^b	150,800 \pm 949.58 ^a	750 \pm 12.49 ^b
<i>Ziziphus</i> of Banamba	31.00 \pm 4.36 ^b	151,000 \pm 525.75 ^a	780 \pm 10.00 ^b
<i>Raphia</i> of Sikasso	11.00 \pm 1.73 ^d	90,000 \pm 510.47 ^d	450 \pm 17.32 ^c
p-value	0.26E-8	0.01E-20	0.03E-14
AJR (μg)	400 - 900	60,000	10,000

*The means by column which do not share any letters (a-e) are significantly different at 0.05. AJR: Recommended daily intake for children 9 - 15 years old (Source: Elidrissi Slitine *et al.* (2010) [22]).

❖ Mineral element contents

Table 4 summarizes the contents of mineral elements. It shows that the concentrations of mineral elements are different from one fruit species to another and sometimes from one area to another. These wild fruits contain appreciable quantities of mineral especially iron (Fe), phosphorus (P) and calcium (Ca).

4. Discussion

4.1. Physicochemical Parameters

The physicochemical parameters of the four wild fruits from Banamba and Sikasso were evaluated. The results (**Table 1**) showed that these physicochemical parameters have been varied according to the fruits and according to the provenance (p-value < 0.05). The assessment of pH and titratable acidity are important parameters in the quality control of any foodstuffs. These parameters indicate the evolution of the medium acidity, according to the metabolism of the microorganisms. The results of **Table 1** showed that all the investigated fruits are acidic (pH < 7). So a pH value from 3 to 6 is very favorable to the development of yeasts and molds [13]. In this way, our obtained data denote the preserving difficulties of our fruits because of their favorable pH to microbial activity. Our different samples are quite rich in water with the contents greater than 10% (**Table 1**); which would pose a conservation problem. It is known that for the humidity greater than 10%, the degradation of certain constituents by enzymatic hydrolysis becomes favorable [24]. That would explain the low medium and long terms availability of these fruits on the markets. Therefore, it would be important to develop processes for transforming these fruits for a better conservation.

Table 4. Mineral elements levels.

Fruits and origins	Contents in mg/100g DM							Contents in µg/100g DM				
	Na	K	Ca	P	Fe	Mg	Mn	Zn	Cu	Ni	Pb	Co
<i>Balanites</i> Sik	2.78 ^a	358.10 ^a	111.20 ^d	2273.00 ^a	33.15 ^c	8.80 ^d	0.077 ^f	0.067 ^f	53.11 ^d	23.42 ^c	1.26 ^c	-
<i>Balanites</i> Bba	3.45 ^a	310.21 ^{ab}	297.94 ^c	1141.00 ^c	20.75 ^d	9.82 ^{cd}	0.075 ^g	0.136 ^d	34.38 ^d	21.99 ^d	0.29 ^g	-
<i>Saba</i> Sik	4.45 ^a	294.90 ^{abc}	268.20 ^c	1274.50 ^c	44.65 ^{ab}	27.40 ^a	6.855 ^b	0.397 ^a	230.53 ^a	79.08 ^a	1.34 ^b	-
<i>Saba</i> Bba	3.84 ^a	269.00 ^{abc}	172.90 ^d	1745.00 ^b	51.16 ^a	25.71 ^{ab}	5.601 ^c	0.345 ^b	171.20 ^b	54.90 ^b	0.80 ^e	-
<i>Ziziphus</i> Sik	3.27 ^a	238.80 ^{bcd}	386.50 ^b	1722.80 ^b	30.43 ^c	19.42 ^{abc}	0.188 ^d	0.096 ^e	78.56 ^c	17.34 ^e	0.81 ^d	-
<i>Ziziphus</i> Bba	5.64 ^a	207.30 ^{cd}	297.40 ^c	2312.00 ^a	29.36 ^{cd}	16.96 ^{cd}	0.155 ^e	0.057 ^f	33.59 ^d	8.34 ^f	0.34 ^f	-
<i>Raphia</i> Sik	4.86 ^a	152.00 ^d	866.10 ^a	1533.50 ^{bc}	38.44 ^{bc}	26.35 ^{ab}	14.150 ^a	0.028 ^c	100.50 ^c	6.39 ^g	1.55 ^a	-
p-value	0.754	0.005	0.06E-8	0.0001	0.0002	0.003	0.1E-8	0.6E-20	0.2E-9	0.1E-18	0.1E-16	-
AJR* (mg)	3000 - 4000	1000 - 1200	800 - 1000	800 - 1000	20 - 58	200 - 230	5	15	2 - 5	0.08 - 0.10	0.002	0

*For each parameter, the means by column which do not share any letters (a-g) are significantly different at 0.05. AJR: Recommended daily intake (source: FAO, 2004) [23]. Sik: Sikasso; Bba: Banamba.

4.2. Nutritional Composition

The performed nutritional parameters are presented in **Table 2**. It appears that these parameters are function of species and provenances of fruits (p-value < 0.05).

Protein contents

Found in all living things, the proteins are biopolymers of amino acids essential for growth [25]. The protein contents of our samples have varied significantly from one fruit to another (p-value = 0.001 < 0.05); from 4.53 ± 0.25 g/100g DM for *Raphia* to 5.34 ± 0.52 g/100g DM for *Balanites* from Sikasso (**Table 2**). Makalao *et al.* [10] had registered similar data, 4.81 to 5.46 g/100g DM for the fruits of *Balanites* and *Ziziphus*. On the other hand, the work carried out by Achaglin-kame *et al.* (2019) [9] on *B. aegyptiaca* revealed higher protein contents with 9.19% ± 0.05% DM. Our protein contents are higher than those obtained by Tiendrebeogo *et al.* [26] with the fruits of *Saba* (3.7 to 6.3 g/kg DM) harvested in Burkina Faso. A study has shown that plant protein isolates are used as additives in food products due to their functional properties (emulsifying capacity, water retention capacity, etc.) [27]. This is why these proteins are currently coveted to replace valuably those of animal origin which are not accessible to all because of their high cost.

Carbohydrates levels

The carbohydrates are the most important constituents of the most eatable fruits. They are also responsible for the sweetness of the food [13]. According to the data of **Table 2**, the total sugars contents of the fruits have varied from 53.93 ± 0.61 g/100g DM for *B. aegyptiaca* to 71.02 ± 1.95 g/100g DM for *Z. mauritiana*. As for reducing sugars, the highest levels have been observed in the fruits of *S. senegalensis* (p-value = 0.45E-10 < 0.05). The total sugars contents of our fruits

are higher than those obtained by Makalao *et al.* (2015) [10] which were 10.92% and 13.05% respectively for *Z. mauritiana* and *B. aegyptiaca* collected in Tchad. Likewise, these levels are higher than those obtained with the fruits of *S. senegalensis* (104.50 ± 0.7 to 158.8 ± 1.5 g/kg DM) collected in Burkina Faso [26]. On the opposite a higher amount was obtained by Achaglinkame *et al.* (2019) [9] from *B. aegyptiaca* with $73.63\% \pm 0.38\%$. This richness of our wild fruits in carbohydrates would make them a potential source of calories and would promote their transformation, especially into jams and juices [13] for a better availability and accessibility.

Fat contents

The fats are components of cell structures, reserve substances and constitute a cell energy source. Our investigated wild fruits showed relatively low fat contents (Table 2), apart from those of *R. sudanica* with 16.49 ± 0.49 g/100g DM. Lesser amounts of fat were also recorded by others authors from Balanites fruits: 0.15 - 0.67 g/100g for Amadou (2016) [11] and $2.58\% \pm 0.37\%$ for Achaglinkame *et al.* (2019) [9]. Considering this low fat content, these wild fruits could be recommended to the obese and diabetic patients or people in overweight.

Energy values

Our results show that the calorific power of all our fruits is low (Table 2) comparatively to the recommended daily allowances. Therefore, they could be recommended in the diet of diabetic and overweight people; because a relationship between the calorific power and these pathologies was reported [26].

Vitamins contents

Appreciate amounts of vitamins A, C and E have been recorded in our wild fruit extracts. For all the vitamins measured, there were an inter-fruit variation (p-value < 0.05) but no significant variation between the zones (p-value > 0.05), except for the fruits of *S. senegalensis* for the vitamin C (Table 3). Our levels of vitamin C are higher than those obtained by Makalao *et al.* [10] which were 8.57 mg/100g and 137.56 ± 0.26 mg/100g respectively for the fruits of *B. aegyptiaca* and *Z. mauritiana*. Others studies showed similar quantities of vitamin A from *B. aegyptiaca* fruits: Achaglinkame *et al.* [9] recorded 0.84 ± 0.03 mg/100g DM and 0.25 - 0.81 mg/g DM were obtained by Murthy *et al.* [28]. On the other side, higher amounts of vitamin C were obtained by Achaglinkame *et al.* (2019) [9] with 105.97 ± 2.57 mg/100g DM from *B. aegyptiaca*. Likewise, our contents were low than those obtained by Cisse *et al.* (2019) [29] with the fruits of *S. senegalensis* which were 154 to 198 mg/100g. As for vitamin E, our data were close to those of Kini *et al.* [8] who noted 31 µg/100g and 103 µg/100g respectively for the fruits of *B. aegyptiaca* and *Z. mauritiana*. The same authors registered 1.559 µg/100g of vitamin A for the fruit juice of *S. senegalensis*. In human trials, some supplementation experiments had shown the potential benefits of vitamins (C and E) combined to other compounds: reduction in adiposity, lowering of triglycerides and cholesterol levels; betterment of insulin sensitivity [30] and reduction inflammatory response [31] [32]. Hence, our wild fruits would constitute a significant source of vitamins and could contribute to reduce the anomalies linked to certain vitamin

deficiencies and to fight against the pathologies linked to oxidative stress.

Mineral contents

Table 4 summarizes the contents of mineral elements which are micronutrients involved in a wide range of physiological functions such as mineralization, the control of hydromineral balance, the enzymatic, hormonal, nervous and immune systems. For example potassium (K), in equilibrium with sodium, is an essential element for the activity of nervous and muscle cells. In our study, the highest **potassium (P)** contents were 358.10 mg/100g DM for Balanites of Sikasso and the lowest 152.00 mg/100g DM for Raphia (**Table 4**). The data reveal also that our samples could be a hopeful source of phosphorus (P) with the amounts altered from 1141.00 to 2312.00 mg/100g DM (**Table 4**).

Calcium (Ca) is a major component of bone mineralization and growth, especially in children under 18 years old. The calcium contents varied from 111.20 mg/100g for Balanites to 866.10 mg/100g for Raphia. Makalao *et al.* [10] registered lower levels with the fruits of Balanites (37.68 to 126.04 mg/100g DM) and Ziziphus (26.99 to 69.75 mg/100g DM).

Iron (Fe) is an essential component in the composition of hemoglobin in red blood cells, in muscle myoglobin and in many enzymatic reactions. The very promising data were obtained for iron: from 20.57 mg/100g DM for Balanites to 51.16 mg/100g DM for Saba (**Table 4**). Based on this richness in iron, these wild fruits could be recommended in the fight against anemia, especially in the pregnant women in whom a drug supplementation is frequently used during the pregnancy [33].

Manganese (Mn) is a trace element whose the main functions relate to carbohydrate (synthesis and secretion of insulin) and lipid metabolisms as well as the detoxification of free radicals from oxygen [34]. The results show that the fruits of Raphia and Saba were very rich in manganese with respectively 14.150 mg/100g DM and 6.855 mg/100g DM (**Table 4**). This potentiality could be exploited in the management of diabetes and other pathologies linked to oxidative stress.

The copper, manganese and zinc contents obtained from our wild fruits would be interesting in the repair of possible oxidative damage, since these trace elements are the cofactors of numerous enzymes which have antioxidant activities [35].

Despite its negative connotation as a pollutant and carcinogenic agent, the nickel (Ni) is an indispensable metal in the metabolism of methionine *via* homocysteine [34]. Our fruits contained the nickel (Ni) but the levels obtained (6.39 to 79.08 µg/100g) (**Table 4**) would not be a danger for the consumption because they were all lower than the maximum dose set by AFSSA (2007) [33] which is 600 µg/day. On the other hand, they were higher than the data registered by Leblanc *et al.* (2004) who revealed that the average nickel content of fruits alters between 1.68 and 5.56 µg/100g. Moreover, Daudet (2012) [36] had already drawn the attention to the micronutrient richness of wild products in these terms: “their contents in various micronutrients seem to be higher than the nutritional content of the agri-

cultural products”. As such, our wild fruits would constitute a potential local source of micronutrients and would be a glimmer of hope in the fight against the micronutrient deficiencies.

5. Conclusion

This work provided a comparative evaluation of physicochemical and nutritional parameters of four underexploited edible wild fruits. The results revealed that the evaluated parameters fluctuate from one fruit to another and sometimes from one zone to another. These picking fruits could be a potential source of macronutrients and calories. They could also offer many micronutrients such as minerals (Fe, Ca, Mn, etc.) and vitamins (A, C and E) which are essential for human nutrition. The fruits of *R. sudanica* due to their high level of calcium could be recommended to improve bone mineralization and growth, mostly in children. The richness in the iron of our fruits could make them potential candidates to fight against malnutrition and anemia, mainly in pregnant women. Thereby, in addition to their nutritional potential, these fruits would be promising candidates in the management of pathologies related to oxidative stress. So, to better valorize these edible wild fruits, it would be necessary to develop recipes incorporating these fruits to fortify the food basis in order to contribute to the fight against the malnutrition linked to certain micronutrient deficiencies.

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Conflicts of Interest

The authors have no conflicts of interest from these data.

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